



THE AMERICAN ASSOCIATION FOR  
LABORATORY ACCREDITATION  
**ACCREDITED LABORATORY**

A2LA has accredited

**TRS-RENTELCO**  
**DFW Airport, TX**

for technical competence in the field of

**Calibration**

This laboratory is accredited in accordance with the recognized International Standard ISO/IEC 17025:2005 *General Requirements for the Competence of Testing and Calibration Laboratories*. This laboratory also meets the requirements of ANSI/NCSL Z540-1-1994 and any additional program requirements in the field of calibration. This accreditation demonstrates technical competence for a defined scope and the operation of a laboratory quality management system (*refer to joint ISO-ILAC-IAF Communiqué dated 18 June 2005*).

Presented this 8<sup>th</sup> day of February 2008.

A handwritten signature in black ink that reads "Peter R. Ringer".

President  
For the Accreditation Council  
Certificate Number 2681.01  
Valid to April 30, 2010



For the calibrations to which this accreditation applies, please refer to the laboratory's Calibration Scope of Accreditation.

SCOPE OF ACCREDITATION TO ISO/IEC 17025:2005  
& ANSI/NCSL Z540-1-1994

TRS-RENTELCO  
1830 W. Airfield Dr.  
DFW Airport, TX 75261  
Charles McPherson      Phone: 972-456-4582

CALIBRATION

Valid To: April 30, 2010

Certificate Number: 2681.01

In recognition of the successful completion of the A2LA evaluation process, accreditation is granted to this laboratory to perform the following calibrations<sup>1</sup>:

I. Electrical – DC/Low Frequency

Parameter/Equipment	Range	Best Uncertainty <sup>2, 3, 8</sup> ( $\pm$ )	Comments
DC Voltage – Measure	(0 to 200) mV (0.2 to 2) V (2 to 20) V (20 to 200) V (200 to 1000) V	5 $\mu$ V/V + 0.1 $\mu$ V 3.5 $\mu$ V/V + 0.4 $\mu$ V 3.5 $\mu$ V/V + 4 $\mu$ V 5.5 $\mu$ V/V + 40 $\mu$ V 5.5 $\mu$ V/V + 500 $\mu$ V	Fluke 8508A
DC Voltage – Generate			
Fixed Points	0.1 V 1 V 10 V 100 V 1000 V	3.5 $\mu$ V/V 3.2 $\mu$ V/V 3 $\mu$ V/V 3.2 $\mu$ V/V 3.5 $\mu$ V/V	Fluke 732 DC/Fluke 752A/Fluke 8508A
Variable DC	(0 to 220) mV (0.22 to 2.2) V (2.2 to 11) V (11 to 22) V (22 to 220) V (220 to 1100) V	7.5 $\mu$ V/V + 0.4 $\mu$ V 5 $\mu$ V/V + 0.7 $\mu$ V 3.5 $\mu$ V/V + 2.5 $\mu$ V 3.5 $\mu$ V/V + 4 $\mu$ V 5 $\mu$ V/V + 40 $\mu$ V 6.5 $\mu$ V/V + 400 $\mu$ V	Fluke 5720A

Parameter/Equipment	Range	Best Uncertainty <sup>2, 8</sup> ( $\pm$ )	Comments
DC Current – Generate	(0 to 220) $\mu$ A (0.22 to 2.2) mA (2.2 to 22) mA (22 to 220) mA (0.22 to 2.2) A (2.2 to 11) A	50 $\mu$ A/A + 8 nA 50 $\mu$ A/A + 8 nA 50 $\mu$ A/A + 80 nA 60 $\mu$ A/A + 0.8 $\mu$ A 80 $\mu$ A/A + 25 $\mu$ A 0.036 % + 480 $\mu$ A	Fluke 5720A /5725A
DC Current – Measure	10 $\mu$ A 100 $\mu$ A 1 mA 10 mA 100 mA 1 A 10 A 100 A 300 A	6 $\mu$ A/A 6.7 $\mu$ A/A 5.3 $\mu$ A/A 5.3 $\mu$ A/A 7.1 $\mu$ A/A 7.1 $\mu$ A/A 7.1 $\mu$ A/A 7.1 $\mu$ A/A 7.1 $\mu$ A/A	Fluke 8508A/Guildline 9211A shunt
AC Voltage – Measure <sup>4</sup>			
2.2 mV	(10 to 20) Hz (20 to 40) Hz 40 Hz to 20 kHz (20 to 50) kHz (50 to 100) kHz (100 to 300) kHz (300 to 500) kHz 500 kHz to 1 MHz	0.17 % + 1.3 $\mu$ V 0.07 % + 1.3 $\mu$ V 0.042 % + 1.3 $\mu$ V 0.081 % + 2 $\mu$ V 0.12 % + 2.5 $\mu$ V 0.23 % + 4 $\mu$ V 0.24 % + 8 $\mu$ V 0.35 % + 8 $\mu$ V	Fluke 5790A
7 mV	(10 to 20) Hz (20 to 40) Hz 40 Hz to 20 kHz (20 to 50) kHz (50 to 100) kHz (100 to 300) kHz (300 to 500) kHz 500 kHz to 1 MHz	0.085 % + 1.3 $\mu$ V 0.037 % + 1.3 $\mu$ V 0.021 % + 1.3 $\mu$ V 0.04 % + 2 $\mu$ V 0.06 % + 2.5 $\mu$ V 0.12 % + 4 $\mu$ V 0.13 % + 8 $\mu$ V 0.23 % + 8 $\mu$ V	
22 mV	(10 to 20) Hz (20 to 40) Hz 40 Hz to 20 kHz (20 to 50) kHz (50 to 100) kHz (100 to 300) kHz (300 to 500) kHz 500 kHz to 1 MHz	0.029 % + 1.3 $\mu$ V 0.019 % + 1.3 $\mu$ V 0.011 % + 1.3 $\mu$ V 0.021 % + 2 $\mu$ V 0.031 % + 2.5 $\mu$ V 0.081 % + 4 $\mu$ V 0.089 % + 8 $\mu$ V 0.17 % + 8 $\mu$ V	

Parameter/Equipment	Range	Best Uncertainty <sup>2, 8</sup> ( $\pm$ )	Comments
AC Voltage – Measure <sup>4</sup> (cont)			
70 mV	(10 to 20) Hz (20 to 40) Hz 40 Hz to 20 kHz (20 to 50) kHz (50 to 100) kHz (100 to 300) kHz (300 to 500) kHz 500 kHz to 1 MHz	0.024 % + 1.5 $\mu$ V 0.012 % + 1.5 $\mu$ V 65 $\mu$ V/V + 1.5 $\mu$ V 0.013 % + 2 $\mu$ V 0.026 % + 2.5 $\mu$ V 0.051 % + 4 $\mu$ V 0.067 % + 8 $\mu$ V 0.11 % + 8 $\mu$ V	Fluke 5790A
220 mV	(10 to 20) Hz (20 to 40) Hz 40 Hz to 20 kHz (20 to 50) kHz (50 to 100) kHz (100 to 300) kHz (300 to 500) kHz 500 kHz to 1 MHz	0.021 % + 1.5 $\mu$ V 85 $\mu$ V/V + 1.5 $\mu$ V 38 $\mu$ V/V + 1.5 $\mu$ V 69 $\mu$ V/V + 2 $\mu$ V 0.016 % + 2.5 $\mu$ V 0.025 % + 4 $\mu$ V 0.038 % + 8 $\mu$ V 0.1 % + 8 $\mu$ V	
700 mV	(10 to 20) Hz (20 to 40) Hz 40 Hz to 20 kHz (20 to 50) kHz (50 to 100) kHz (100 to 300) kHz (300 to 500) kHz 500 kHz to 1 MHz	0.021 % + 1.5 $\mu$ V 76 $\mu$ V/V + 1.5 $\mu$ V 33 $\mu$ V/V + 1.5 $\mu$ V 51 $\mu$ V/V + 2 $\mu$ V 79 $\mu$ V/V + 2.5 $\mu$ V 0.018 % + 4 $\mu$ V 0.03 % + 8 $\mu$ V 0.096 % + 8 $\mu$ V	
2.2 V	(10 to 20) Hz (20 to 40) Hz 40 Hz to 20 kHz (20 to 50) kHz (50 to 100) kHz (100 to 300) kHz (300 to 500) kHz 500 kHz to 1 MHz	0.02 % 66 $\mu$ V/V 24 $\mu$ V/V 46 $\mu$ V/V 71 $\mu$ V/V 0.016 % 0.026 % 0.09 %	
7 V	(10 to 20) Hz (20 to 40) Hz 40 Hz to 20 kHz (20 to 50) kHz (50 to 100) kHz (100 to 300) kHz (300 to 500) kHz 500 kHz to 1 MHz	0.02 % 67 $\mu$ V/V 24 $\mu$ V/V 48 $\mu$ V/V 81 $\mu$ V/V 0.019 % 0.04 % 0.12 %	

Parameter/Equipment	Range	Best Uncertainty <sup>2, 8</sup> ( $\pm$ )	Comments
AC Voltage – Measure <sup>4</sup> (cont)			
22 V	(10 to 20) Hz (20 to 40) Hz 40 Hz to 20 kHz (20 to 50) kHz (50 to 100) kHz (100 to 300) kHz (300 to 500) kHz 500 kHz to 1 MHz	0.02 % 67 $\mu$ V/V 27 $\mu$ V/V 48 $\mu$ V/V 81 $\mu$ V/V 0.019 % 0.04 % 0.12 %	Fluke 5790A
70 V	(10 to 20) Hz (20 to 40) Hz 40 Hz to 20 kHz (20 to 50) kHz (50 to 100) kHz	0.02 % 68 $\mu$ V/V 32 $\mu$ V/V 57 $\mu$ V/V 94 $\mu$ V/V	
220 V	(10 to 20) Hz (20 to 40) Hz 40 Hz to 20 kHz (20 to 50) kHz (50 to 100) kHz	0.02 % 68 $\mu$ V/V 31 $\mu$ V/V 69 $\mu$ V/V 98 $\mu$ V/V	
700 V	(10 to 20) Hz (20 to 40) Hz 40 Hz to 20 kHz (20 to 50) kHz (50 to 100) kHz	0.02 % 99 $\mu$ V/V 41 $\mu$ V/V 0.013 % 0.05 %	
1000 V	(10 to 20) Hz (20 to 40) Hz 40 Hz to 20 kHz (20 to 50) kHz (50 to 100) kHz	0.02 % 99 $\mu$ V/V 38 $\mu$ V/V 0.013 % 0.05 %	
AC Voltage – Generate			
2.2 mV	(10 to 20) Hz (20 to 40) Hz 40 Hz to 20 kHz (20 to 50) kHz (50 to 100) kHz (100 to 300) kHz (300 to 500) kHz 500 kHz to 1 MHz	0.024 % + 4 $\mu$ V 90 $\mu$ V/V + 4 $\mu$ V 80 $\mu$ V/V + 4 $\mu$ V 0.02 % + 4 $\mu$ V 0.05 % + 5 $\mu$ V 0.11 % + 10 $\mu$ V 0.14 % + 20 $\mu$ V 0.27 % + 20 $\mu$ V	Fluke 5720A

Parameter/Equipment	Range	Best Uncertainty <sup>2, 8</sup> ( $\pm$ )	Comments
AC Voltage – Generate (cont)			
22 mV	(10 to 20) Hz (20 to 40) Hz 40 Hz to 20 kHz (20 to 50) kHz (50 to 100) kHz (100 to 300) kHz (300 to 500) kHz 500 kHz to 1 MHz	0.024 % + 4 $\mu$ V 90 $\mu$ V/V + 4 $\mu$ V 80 $\mu$ V/V + 4 $\mu$ V 0.02 % + 4 $\mu$ V 0.05 % + 5 $\mu$ V 0.11 % + 10 $\mu$ V 0.14 % + 20 $\mu$ V 0.27 % + 20 $\mu$ V	Fluke 5720A
220 mV	(10 to 20) Hz (20 to 40) Hz 40 Hz to 20 kHz (20 to 50) kHz (50 to 100) kHz (100 to 300) kHz (300 to 500) kHz 500 kHz to 1 MHz	0.024 % + 12 $\mu$ V 90 $\mu$ V/V + 7 $\mu$ V 80 $\mu$ V/V + 7 $\mu$ V 0.02 % + 7 $\mu$ V 0.046 % + 17 $\mu$ V 0.09 % + 20 $\mu$ V 0.14 % + 25 $\mu$ V 0.27 % + 45 $\mu$ V	
2.2 V	(10 to 20) Hz (20 to 40) Hz 40 Hz to 20 kHz (20 to 50) kHz (50 to 100) kHz (100 to 300) kHz (300 to 500) kHz 500 kHz to 1 MHz	0.024 % + 40 $\mu$ V 90 $\mu$ V/V + 15 $\mu$ V 45 $\mu$ V/V + 8 $\mu$ V 75 $\mu$ V/V + 10 $\mu$ V 0.011 % + 30 $\mu$ V 0.042 % + 80 $\mu$ V 0.1 % + 0.2 mV 0.17 % + 0.3 mV	
22 V	(10 to 20) Hz (20 to 40) Hz 40 Hz to 20 kHz (20 to 50) kHz (50 to 100) kHz (100 to 300) kHz (300 to 500) kHz 500 kHz to 1 MHz	0.024 % + 0.4 mV 90 $\mu$ V/V + 0.15 mV 45 $\mu$ V/V + 50 $\mu$ V 75 $\mu$ V/V + 0.1 mV 0.01 % + 0.2 mV 0.028 % + 0.6 mV 0.1 % + 2 mV 0.15 % + 3.2 mV	
220 V	(10 to 20) Hz (20 to 40) Hz 40 Hz to 20 kHz (20 to 50) kHz (50 to 100) kHz	0.024 % + 4 mV 90 $\mu$ V/V + 1.5 mV 52 $\mu$ V/V + 0.6 mV 80 $\mu$ V/V + 1 mV 0.015 % + 2.5 mV	
1100 V	50 Hz to 1 kHz	70 $\mu$ V/V + 3.5 mV	

Parameter/Equipment	Range	Best Uncertainty <sup>2, 8</sup> ( $\pm$ )	Comments
AC Voltage – Measure Wideband <sup>4</sup>			
2.2 mV	(10 to 30) Hz (30 to 120) Hz 120 Hz to 1.2 kHz (120 to 500) kHz 500 kHz to 2 MHz (2 to 10) MHz (10 to 20) MHz (20 to 30) MHz	0.6 % + 1.5 $\mu$ V 0.6 % + 1.5 $\mu$ V 0.6 % + 1.5 $\mu$ V 0.6 % + 1.5 $\mu$ V 0.67 % + 2.5 $\mu$ V 0.77 % + 2.5 $\mu$ V 0.9 % + 2.5 $\mu$ V 1.3 % + 3.5 $\mu$ V	5790A/Option 03 wideband input – 50 $\Omega$
7 mV	(10 to 30) Hz (30 to 120) Hz 120 Hz to 1.2 kHz (120 to 500) kHz 500 kHz to 2 MHz (2 to 10) MHz (10 to 20) MHz (20 to 30) MHz	0.5 % + 7 $\mu$ V 0.5 % + 7 $\mu$ V 0.5 % + 7 $\mu$ V 0.5 % + 7 $\mu$ V 0.57 % + 8 $\mu$ V 0.6 % + 8 $\mu$ V 0.67 % + 8 $\mu$ V 0.87 % + 8 $\mu$ V	
22 mV	(10 to 30) Hz (30 to 120) Hz 120 Hz to 1.2 kHz (120 to 500) kHz 500 kHz to 2 MHz (2 to 10) MHz (10 to 20) MHz (20 to 30) MHz	0.5 % + 13 $\mu$ V 0.5 % + 13 $\mu$ V 0.5 % + 13 $\mu$ V 0.5 % + 13 $\mu$ V 0.57 % + 13 $\mu$ V 0.6 % + 13 $\mu$ V 0.67 % + 13 $\mu$ V 0.87 % + 13 $\mu$ V	
70 mV	(10 to 30) Hz (30 to 120) Hz 120 Hz to 1.2 kHz (120 to 500) kHz 500 kHz to 2 MHz (2 to 10) MHz (10 to 20) MHz (20 to 30) MHz	0.5 % + 30 $\mu$ V 0.5 % + 30 $\mu$ V 0.5 % + 30 $\mu$ V 0.5 % + 30 $\mu$ V 0.55 % + 30 $\mu$ V 0.6 % + 30 $\mu$ V 0.65 % + 30 $\mu$ V 0.85 % + 30 $\mu$ V	
220 mV	(10 to 30) Hz (30 to 120) Hz 120 Hz to 1.2 kHz (120 to 500) kHz 500 kHz to 2 MHz (2 to 10) MHz (10 to 20) MHz (20 to 30) MHz	0.4 % + 80 $\mu$ V 0.4 % + 80 $\mu$ V 0.4 % + 80 $\mu$ V 0.4 % + 80 $\mu$ V 0.45 % + 80 $\mu$ V 0.5 % + 80 $\mu$ V 0.55 % + 80 $\mu$ V 0.75 % + 80 $\mu$ V	

Parameter/Equipment	Range	Best Uncertainty <sup>2, 8</sup> ( $\pm$ )	Comments
AC Voltage – Measure Wideband <sup>4</sup> (cont)			
700 mV	(10 to 30) Hz (30 to 120) Hz 120 Hz to 1.2 kHz (120 to 500) kHz 500 kHz to 2 MHz (2 to 10) MHz (10 to 20) MHz (20 to 30) MHz	0.4 % + 0.3 mV 0.4 % + 0.3 mV 0.4 % + 0.3 mV 0.4 % + 0.3 mV 0.45 % + 0.3 mV 0.5 % + 0.3 mV 0.55 % + 0.3 mV 0.75 % + 0.3 mV	5790A/Option 03 wideband input – 50 $\Omega$
2.2 V	(10 to 30) Hz (30 to 120) Hz 120 Hz to 1.2 kHz (120 to 500) kHz 500 kHz to 2 MHz (2 to 10) MHz (10 to 20) MHz (20 to 30) MHz	0.35 % + 0.4 mV 0.35 % + 0.4 mV 0.35 % + 0.4 mV 0.35 % + 0.4 mV 0.4 % + 0.4 mV 0.45 % + 0.4 mV 0.5 % + 0.4 mV 0.7 % + 0.4 mV	
7 V	(10 to 30) Hz (30 to 120) Hz 120 Hz to 1.2 kHz (120 to 500) kHz 500 kHz to 2 MHz (2 to 10) MHz (10 to 20) MHz (20 to 30) MHz	0.35 % + 0.8 mV 0.35 % + 0.8 mV 0.35 % + 0.8 mV 0.35 % + 0.8 mV 0.4 % + 0.8 mV 0.45 % + 0.8 mV 0.5 % + 0.8 mV 0.7 % + 0.8 mV	
AC Voltage – Generate Wideband			
11 mV	(10 to 30) Hz 30 Hz to 500 kHz 500 kHz to 2 MHz (2 to 10) MHz (10 to 20) MHz (20 to 30) MHz	1 % + 8 $\mu$ V 0.7 % + 8 $\mu$ V 0.8 % + 11 $\mu$ V 0.9 % + 11 $\mu$ V 1.1 % + 11 $\mu$ V 1.7 % + 11 $\mu$ V	Fluke 5720A option 03 wideband output – 50 $\Omega$
33 mV	(10 to 30) Hz 30 Hz to 500 kHz 500 kHz to 2 MHz (2 to 10) MHz (10 to 20) MHz (20 to 30) MHz	0.9 % + 13 $\mu$ V 0.6 % + 13 $\mu$ V 0.7 % + 16 $\mu$ V 0.8 % + 16 $\mu$ V 1 % + 16 $\mu$ V 1.6 % + 16 $\mu$ V	

Parameter/Equipment	Range	Best Uncertainty <sup>2, 8</sup> ( $\pm$ )	Comments
AC Voltage – Generate Wideband (cont)			
110 mV	(10 to 30) Hz 30 Hz to 500 kHz 500 kHz to 2 MHz (2 to 10) MHz (10 to 20) MHz (20 to 30) MHz	0.9 % + 40 $\mu$ V 0.6 % + 40 $\mu$ V 0.7 % + 43 $\mu$ V 0.8 % + 43 $\mu$ V 1 % + 43 $\mu$ V 1.6 % + 43 $\mu$ V	Fluke 5720A option 03 wideband output – 50 $\Omega$
330 mV	(10 to 30) Hz 30 Hz to 500 kHz 500 kHz to 2 MHz (2 to 10) MHz (10 to 20) MHz (20 to 30) MHz	0.8 % + 0.1 mV 0.5 % + 0.1 mV 0.6 % + 0.11 mV 0.7 % + 0.11 mV 0.9 % + 0.11 mV 1.5 % + 0.11 mV	
1.1 V	(10 to 30) Hz 30 Hz to 500 kHz 500 kHz to 2 MHz (2 to 10) MHz (10 to 20) MHz (20 to 30) MHz	0.8 % + 0.4 mV 0.5 % + 0.4 mV 0.6 % + 0.41 mV 0.7 % + 0.41 mV 0.9 % + 0.41 mV 1.5 % + 0.41 mV	
3.5 V	(10 to 30) Hz 30 Hz to 500 kHz 500 kHz to 2 MHz (2 to 10) MHz (10 to 20) MHz (20 to 30) MHz	0.7 % + 0.5 mV 0.4 % + 0.5 mV 0.5 % + 0.51 mV 0.6 % + 0.51 mV 0.8 % + 0.51 mV 1.4 % + 0.51 mV	
AC Current – Generate			
220 $\mu$ A	40 Hz to 1 kHz	0.012 % + 8 nA	Fluke 5720A /5725A
2.2 mA	40 Hz to 1 kHz	0.012 % + 35 nA	
22 mA	40 Hz to 1 kHz	0.012 % + 0.35 $\mu$ A	
220 mA	40 Hz to 1 kHz	0.012 % + 2.5 $\mu$ A	
2.2 A	20 Hz to 1 kHz	0.026 % + 35 $\mu$ A	
11 A	40 Hz to 1 kHz	0.046 % + 170 $\mu$ A	
AC Current – Measure			
200 $\mu$ A	10 Hz to 10 kHz	0.031 % + 0.02 $\mu$ A	Fluke 8508A
2 mA	10 Hz to 10 kHz	0.03 % + 0.2 $\mu$ A	
20 mA	10 Hz to 10 kHz	0.03 % + 2 $\mu$ A	
200 mA	10 Hz to 10 kHz	0.03 % + 20 $\mu$ A	
2 A	10 Hz to 2 kHz	0.062 % + 200 $\mu$ A	
2 A	(2 to 10) kHz	0.072 % + 200 $\mu$ A	
20 A	10 Hz to 2 kHz	0.082 % + 2 mA	
20 A	(2 to 10) kHz	0.25 % + 2 mA	

Parameter/Equipment	Range	Best Uncertainty <sup>2, 8</sup> ( $\pm$ )	Comments	
Resistance – Generate Fixed Point	1 m $\Omega$ 10 m $\Omega$ 100 m $\Omega$ 1 $\Omega$ 1.9 $\Omega$ 10 $\Omega$ 19 $\Omega$ 100 $\Omega$ 190 $\Omega$ 1 k $\Omega$ 1.9 k $\Omega$ 10 k $\Omega$ 19 k $\Omega$ 100 k $\Omega$ 190 k $\Omega$ 1 M $\Omega$ 1.9 M $\Omega$ 10 M $\Omega$ 19 M $\Omega$ 100 M $\Omega$	0.05 % 0.01 % 0.01 % 95 $\mu\Omega/\Omega$ 95 $\mu\Omega/\Omega$ 23 $\mu\Omega/\Omega$ 23 $\mu\Omega/\Omega$ 10 $\mu\Omega/\Omega$ 10 $\mu\Omega/\Omega$ 8.5 $\mu\Omega/\Omega$ 8.5 $\mu\Omega/\Omega$ 8.5 $\mu\Omega/\Omega$ 8.5 $\mu\Omega/\Omega$ 11 $\mu\Omega/\Omega$ 11 $\mu\Omega/\Omega$ 20 $\mu\Omega/\Omega$ 21 $\mu\Omega/\Omega$ 40 $\mu\Omega/\Omega$ 47 $\mu\Omega/\Omega$ 0.01 %	Guildline 9211A shunt/Fluke 5720A	
Resistance – Measure	2 $\Omega$ 20 $\Omega$ 200 $\Omega$ 2 k $\Omega$ 20 k $\Omega$ 200 k $\Omega$ 2 M $\Omega$ 20 M $\Omega$ 200 M $\Omega$ 2 G $\Omega$ 20 G $\Omega$	17 $\mu\Omega/\Omega + 4 \mu\Omega$ 9.5 $\mu\Omega/\Omega + 14 \mu\Omega$ 8 $\mu\Omega/\Omega + 50 \mu\Omega$ 8 $\mu\Omega/\Omega + 0.5 \text{ m}\Omega$ 8 $\mu\Omega/\Omega + 5 \text{ m}\Omega$ 8 $\mu\Omega/\Omega + 50 \text{ m}\Omega$ 9 $\mu\Omega/\Omega + 1 \Omega$ 20 $\mu\Omega/\Omega + 0.1 \text{ k}\Omega$ 0.012% + 10 k $\Omega$ 0.15 % + 1 M $\Omega$ 0.15 % + 10 M $\Omega$	Fluke 8508A	
Capacitance – Generate	1 nF 10 nF 100 nF 1 $\mu\text{F}$ 10 $\mu\text{F}$ 100 $\mu\text{F}$ 1 mF 10 mF 100 mF	(0.01 to 10) kHz (0.01 to 1) kHz (0.01 to 1) kHz (10 to 600) Hz (10 to 150) Hz (10 to 80) Hz (0 to 20) Hz (0 to 2) Hz (0 to 0.2) Hz	0.05 % + 0.01 nF 0.25 % + 0.01 nF 0.25 % + 0.1 nF 0.25 % + 1 nF 0.25 % + 10 nF 0.45 % + 0.1 $\mu\text{F}$ 0.45 % + 1 $\mu\text{F}$ 0.45 % + 10 $\mu\text{F}$ 1.1 % + 0.1 mF	Fluke 5520A

## II. Electrical – RF & Microwave

Parameter/Equipment	Range	Best Uncertainty <sup>2, 5, 8</sup> ( $\pm$ )	Comments
Amplitude Modulation – Measure			
Rate: 20 Hz to 10 kHz Depths: to 99 %	150 kHz to 10 MHz	3 % + 1 digit	Agilent 8902A
Rate: 50 Hz to 10 kHz Depths: 5 % to 99 %	150 kHz to 10 MHz	2 % + 1 digit	
Rate: 20 Hz to 10 kHz Depths: to 99 %	10 MHz to 1300 MHz	3 % + 1 digit	
Rate: 50 Hz to 10 kHz Depths: 5 % to 99 %	10 MHz to 1300 MHz	1 % + 1 digit	
Frequency Modulation – Measure			
Rate: 20 Hz to 10 kHz Dev.: $\leq$ 40 kHz peak	250 kHz to 10 MHz	2 % + 1 digit	Agilent 8902A
Rate: 50 Hz to 100 kHz Dev.: $\leq$ 40 kHz peak	10 MHz to 1300 MHz	1 % + 1 digit	
Rate: 20 Hz to 200 kHz Dev.: $\leq$ 40 kHz peak	10 MHz to 1300 MHz	5 % + 1 digit	
Phase Modulation – Measure			
Rate: 200 Hz to 1 kHz Dev.: $\leq$ 40 Radians peak	150 kHz to 10 MHz	4 % + 1 digit	Agilent 8902A
Rate: 200 Hz to 10 kHz Dev.: $\leq$ 4 Radians peak	150 kHz to 10 MHz	4 % + 1 digit	
Rate: 200 Hz to 1 kHz Dev.: $\leq$ 40 Radians peak	10 MHz to 1300 MHz	3 % + 1 digit	
Rate: 200 Hz to 20 kHz Dev.: $\leq$ 4 Radians peak	10 MHz to 1300 MHz	3 % + 1 digit	

Parameter/Equipment	Range	Best Uncertainty <sup>2, 5, 8</sup> ( $\pm$ )	Comments
Sine Distortion – Measure -99.99 to 0 dB -99.99 to 0 dB	20 Hz to 20 kHz (20 to 100) kHz	1.2 dB 2.4 dB	Agilent 8903B
Tuned RF Level Ranges (10 dBm step) (0 to -100) dBm (-100 to -120) dBm	(2.5 to 1300) MHz	0.006 dB/10 dB step + 0.015 dB + 1 digit  0.06 dB/10 dB step + 0.015 dB + 1 digit	Agilent 8902A/50
RF Power – Generate Up to 23.98 dBm Up to 10 dBm Up to 10 dBm Up to 5 dBm Up to 5 dBm	100 $\mu$ Hz to 15 MHz 10 MHz to 2 GHz (2 to 26.5) GHz (26.5 to 40) GHz (40 to 50) GHz	0.3 dB 1.2 dB 1.3 dB 0.8 dB 1.5 dB	Agilent 33120A Agilent 83650B
RF Attenuation – Generate 1 dB 2 dB 3 dB 4 dB 5 dB 6 dB 7 dB 8 dB 9 dB 10 dB 11 dB  10 dB 20 dB 30 dB 40 dB 50 dB 60 dB 70 dB 80 dB 90 dB 100 dB 110 dB	50 MHz  50 MHz	0.007 dB 0.007 dB 0.007 dB 0.007 dB 0.009 dB 0.009 dB 0.01 dB 0.01 dB 0.009 dB 0.01 dB 0.011 dB  0.01 dB 0.014 dB 0.019 dB 0.024 dB 0.028 dB 0.033 dB 0.037 dB 0.049 dB 0.061 dB 0.072 dB 0.084 dB	Agilent 8494 series  Agilent 8496 series

Parameter/Equipment	Range	Best Uncertainty <sup>2</sup> ( $\pm$ )	Comments
Phase Noise – Measurement 1 Hz to 1 MHz Offset (1 to 100) MHz Offset	5 MHz to 50 GHz	2 dB	Agilent E5505A
	5 MHz to 50 GHz	4 dB	
Reflection S <sub>11</sub> /S <sub>22</sub> – Measure	300 kHz to 1.3 GHz	0.012 Lin	Agilent 8753ES/85032B Type N Connectors
	(1.3 to 3) GHz	0.013 Lin	
	(3 to 6) GHz	0.014 Lin	
Absolute RF Power – Measure (-70 to -30) dBm (-30 to 10) dBm (10 to 20) dBm (-70 to -30) dBm (-30 to 10) dBm (10 to 20) dBm (-70 to -30) dBm (-30 to 10) dBm (10 to 20) dBm (-70 to -30) dBm (-30 to 10) dBm (10 to 20) dBm	100 kHz to 4.2 GHz	0.05 dB	Agilent E4419/8481D-H70 N type Connector
		0.04 dB 0.08 dB	Agilent E4419/8482A-H84 N type Connector
	10 MHz to 18 GHz	0.05 dB	Agilent E4419/8481D-H84 N type Connector
		0.04 dB 0.08 dB	Agilent E4419/8481A-H84 N type Connector
	50 MHz to 26.5 GHz	0.06 dB	Agilent E4419/8485D-H84 3.5 mm Connector
		0.05 dB 0.09 dB	Agilent E4419/8485A-H84 3.5 mm Connector
	50 MHz to 50 GHz	0.06 dB	Agilent E4419/8487D-H84 2.4 mm Connector
		0.05 dB 0.04 dB	Agilent E4419/8487A-H84 2.4 mm Connector
Pulse Modulation – Measure Rise Fall	10 % to 90 % Pulse Envelope	16 picoseconds <sup>6</sup>	Agilent 54750A/83484A
	10 % to 90 % Pulse Envelope		

Parameter/Equipment	Range	Best Uncertainty <sup>2, 7</sup> (±)	Comments
Digital Modulation – Measure Carrier: 2 MHz to 2.65 GHz  Phase Error for Modulation Types: MSK, GMSK, BPSK, DQPSK, n/4DQPSK, 8PSK, 16QAM and 32QAM	Mod Frequency Span 1 Hz to 100 kHz (0.1 to 1) MHz 1 MHz to 2.65 GHz	0.35 % rms 0.58 % rms 1.2 % rms	Agilent 89441A
Phase Error for Modulation Types: MSK, GMSK, BPSK, DQPSK, n/4DQPSK, 8PSK, 16QAM and 32QAM	Mod Frequency Span 1 Hz to 100 kHz (0.1 to 1) MHz 1 MHz to 2.65 GHz	0.2 ° rms 0.4 ° rms 0.66 ° rms	
Error Vector Magnitude for FSK Modulation	Mod Frequency: 3.2 kHz 1.152 MHz	0.58 % rms 1.7 % rms	
Phase Error for FSK Modulation	Mod Frequency: 3.2 kHz 1.152 MHz	0.35 % rms (14 Hz) 1.2 % rms (2.9 kHz)	
Error Vector Magnitude for Modulation Types: QPSK and OQPSK	Mod Frequency: 2.6 MHz	1.0 % rms	
Phase Error for Modulation Types: QPSK and OQPSK	Mod Frequency: 2.6 MHz	0.66 ° rms	

### III. Time & Frequency

Parameter/Equipment	Range	Best Uncertainty <sup>2, 8</sup> (±)	Comments
Frequency – Generate	10 µHz to 15 MHz  10 MHz to 50 GHz	2 pHz/Hz  2 pHz/Hz	Agilent 33120A phase locked to Agilent 5071A  Agilent 83650B phase locked to Agilent 5071A
Frequency – Measuring Equipment	10 MHz 10 µHz to 12.4 GHz	2 pHz/Hz 2 pHz/Hz	Agilent 5071A Agilent 53132A phase locked

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<sup>1</sup> This laboratory offers commercial calibration service.

<sup>2</sup> “Best Uncertainty” is the smallest uncertainty of measurement that a laboratory can achieve within its scope of accreditation when performing more or less routine calibrations of nearly ideal measurement standards of nearly ideal measuring equipment. Best uncertainties represent expanded uncertainties expressed at approximately the 95 % level of confidence, usually using a coverage factor of  $k = 2$ . The best uncertainty of a specific calibration performed by the laboratory may be greater than the best uncertainty due to the behavior of the customer’s device and to influences from the circumstances of the specific calibration.

<sup>3</sup> Based on using the Fluke 8508A at the temperature (T<sub>Cal</sub>) it was calibrated  $\pm 5$  °C, 4 Hr. warm up, maximum resolution and an input zero or offset null performed if temp moves more than  $\pm 1$  °C from temperature at which previous input zero or null was performed. Best measurement uncertainty is based upon 1-year specifications and is read as ppm or percent of reading plus ppm or percent of range. T<sub>Cal</sub> = 23 °C (73.4 °F  $\pm 9$  °F).

<sup>4</sup> Based on using the Fluke 5790A at the temperature (T<sub>Cal</sub>) it was calibrated  $\pm 5$  °C with 30 minutes warm up. Best measurement uncertainty is based upon 1-year specifications and is read as ppm or percent of reading plus fixed amount. T<sub>Cal</sub> = 23 °C (73.4 °F  $\pm 9$  °F).

<sup>5</sup> Agilent 8902A Modulation Resolution

AM 0 % to 9.99 %; 1 digit = 0.01 % / 10 % to 99.9%; 1 digit = 0.1 %

FM 0 to 3.999 kHz: 1 digit = 1 Hz / 4.00 to 39.99 kHz: 1 digit = 10 Hz / 40.0 to 400.0 kHz: 1 digit = 100Hz

PM 0 to 3.999 Radian; 1 digit = 0.001 Radian / 4.00 to 39.99 Radian: 1 digit = 0.01 Radian

Tuned RF 1 digit = 0.001 dB.

<sup>6</sup> Transition time characteristic calculated from  $T = 0.35 / \text{Bandwidth}$  (26.5 GHz)

<sup>7</sup> “rms” refers to root mean square

<sup>8</sup> In a statement of Best Uncertainty, percentage refers to percent of reading, unless otherwise noted.